# AN EXPERIMENTAL STUDY OF CORRELATIONS IN THE DEVELOPMENT OF THE ELECTRON-PHOTON CASCADES

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ABSTRACT

In terms of the experimental data on the development of the electron-photon cascades (EPC) in Pb from electrons and photons of cosmic rays in the tens GeV energy region a calculation of correlations between the characteristics of longitudinal and lateral development of the EPC as well as those between fluctuations of the cascade particle numbers at different stages of the cascade development, is being carried out. The results obtained are compared to the numerical EPC calculations.

## 1. INTRODUCTION

Among methods characterizing the properties of the cascade processes special attention is drawn to the calculation of correlation between different features of the cascade. Note, a sequence of the correlation coefficients (time-correlation $r(\tau)$) determining a random relation between fluctuations of the cascade particle number $u(E_0,t)=n(E_0,t)-\overline{n(E_0,t)}$ at the depth $t$ in a given cascade with the energy $E_0$ and $u(E_0,t+\tau)$ at the depth $t+\tau$ in the same cascade, gives a fairly deep insight into the inner structure of the process. The available data on correlations in the longitudinal development of the EPC obtained by numerical methods [1÷4] needs to be experimentally tested.

## 2. EXPERIMENTAL SET-UP "PHOTON"

With the aid of the experimental set-up PHOTON [5] the EPC's from single electrons and photons of cosmic rays in the energy range of tens GeV have been measured. The EPC-detecting section is a single Pb-Ar calorimeter made as a steel tank filled with argon at a pressure of 16 atm, inside of which 16 Pb plates are placed (the width of the first 11 plates is $0.9\,t_0$, of the rest 5 - $1.77\,t_0$, where the radiative unit $t_0$ is 7,4 g/cm$^2$). Between the plates on the iso lators 16 steel strings 0,5 mm of thickness spaced between 3 cm are stretched. Thus obtained 16 ionization chambers (IL) lack in each IL hollow walls and diaphragms, therefore, there is practically no transition effect. To study a spatial development of the EPC strings in the neighbouring IL's were perpendicular placed. PHOTON was exposed at the height of 3160 m over the sea level. Principles of the initial information selection allowed us to take 383 EPC's for analysis. Statistical simulation of experimental conditions and IL calibration showed that the error in measuring $E_0$, and the number of cascade particles $n(E_0,t)$ is approximately the same being averaged as $\sim 7\%$.

3. RESULTS AND DISCUSSIONS

Comparison of a typical experimental time-correlation $r(\tau)$ with results from [4] by the incomplete Monte-Carlo method shows good agreement (Fig. 1). Fit of $r(\tau)$ to the time-correlations of simple autoregression Marcoff and Yule models in Fig. 1 is unsatisfactory, especially for large $\tau$. However, the rms deviation of $r(\tau)$ values is known to increase with $\tau$ and after a small quantity of runs ($\sim$ 20-30) is comparable with $r(\tau)$ for large $\tau$, the significance level being $\sim$ 0,4 [6,7]. In this case following [7] there are no $u(t)$ fluctuations, a series of $u(t)$ where $t$ is determined by $t_0$, can be described by the Marcoff model, i.e. there is a correlation only between $u(t)$ and $u(t+1)$. The corre-

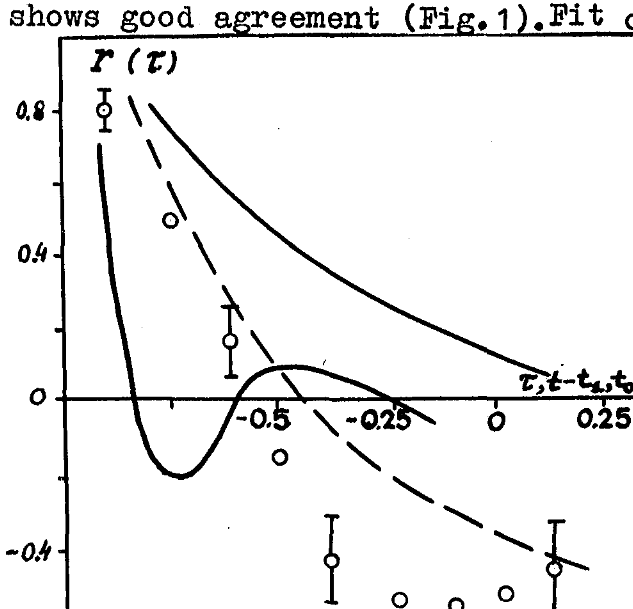


Fig. 1 Time-correlation $r(\tau)$ in the EPC. o - the present experiment, (--) - calculation 4, 1-Marcoff model, 2 - Yule model.

lation interval being $\tau_0 = \int |r(\tau)| d\tau$ [8], or "separation" between depths in $t_0$ at which cascade fluctuations can be considered as independent, fairly strongly changes with $E_0$ from $2{,}5 t_0$ for $E_0 \approx 30$ GeV up to $3{,}5 t_0$ for $E_0 \approx 80$ GeV. Therefore, with the increase of $E_0$ the values of $r(E_0, t, \tau=1)$ grow through $t_0$, and the minimum of $r(E_0, t, \tau+1)$ shifts towards the deep depth (Fig.2).

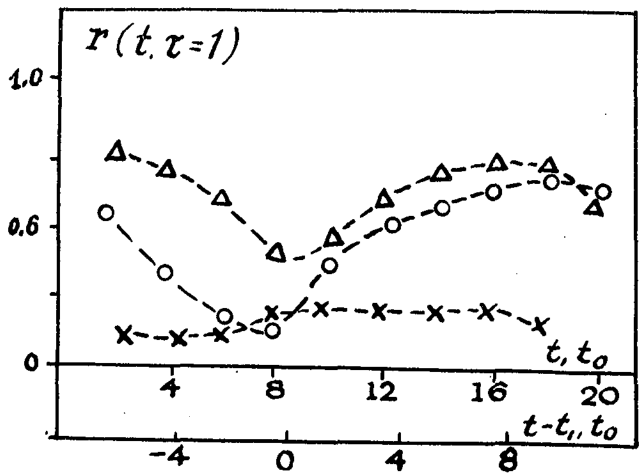


Fig.2 Experimental correlations of $r(t, \tau=1)$. o - $E_0$=30 GeV, Δ - $E_0$= 80 GeV, x - for the EPC with $E_0$ = 80 GeV in the central approach.

The profile of $r(E_0, t, \tau+1)$ coincides with the calculation results [2,3]. Note, that occurence of anticorrelations for large $\tau$ is readily explained by the EPC energy conservation law: fluctuations for one region of depths should be compensated by those in the other part of the cascade development. It is known that the central approach [8] allows us to study separately fluctuations directly of the cascade shape $u_c$ and those of the shift $u_\lambda$. As our calculations showed the experimental time-correlations for fluctuations $u_c$ are typical for a set of independent random quantities (Fig.2), the distribution of $u_c$ being obeyed to the Gauss law within the EPC development. Consider a relation between fluctuations $u_\lambda$ and those of the "center-of-gravity" of the cascade curve $t_1 = \int t n(E_0,t) dt / \int n(E_0,t) dt$, the latter being rather considerable: $\sigma_{t_1}$= 1,5 for $E_0$=30 GeV. The value of the area under the transition curve $\rho(t)$ can serve as an estimate for the absorbed energy in the cascade, and thus, characterize the cascade particle behaviour [9]. Correlations between $\rho(t)$ at the early stages of the EPC development $(t \leqslant 2t_0)$ and $t_1$ turned out to be rather high: $\sim 0,55$ and $\sim 0,70$ for the $EPC^e$ from the primary electrons and the $EPC^\gamma$ from photons, respectively. That is, fluctuations of $t_1$ are generally determined by those of the shift $u_1$. At the same time a correlation between $\rho(t \leq 2t_0)$ and the second central momentum $\mu_2^{1/2}$, characterizing the longitudinal EPC dimension, is small: for $EPC^e \sim 0,16$, for $EPC^\gamma \sim 0,27$. Finally, a correlation between the rms deviation of $r_S$ of the spatial cascade ionization distribution within different depths is not considerable: $\sim 0,3$, being independent of the primary particle type and the depth $t$. A correlation between $r_S$ and $\mu_2^{1/2}$ is practically independent of the primary particle type and $E_0$ tends towards zero in the region of depths up to $(\ln(E_0/\beta)+2)t_0$, then it gradually grows to 0,4 in the deep depth region. Thus, in the wide range of depths lateral and longitudinal dimensions of the EPC are independent.

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